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BRYOZOA IN COORONG - TYPE LAGOONS, SOUTHERN AUSTRALIA

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Summary

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Unilaminar, multiserial colonies of living Bryozoa *(Conopeum aciculata)* are widespread throughout the Coorong Lagoon, South Australia. The bryozoan is an opportunistic species that is able to tolerate variable salinities. It establishes itself early in spring and reaches maturity prior to the drying-out of its nearshore environment in late summer, whereupon it dies. It is intimately associated with serpulid growth in the northern Coorong Lagoon. *C. aciculata* has also been found growing in the hyposaline waters of Lake Clifton, Western Australia, where it is found within clotted, calcareous thrombolites. The age of the Lake Clifton bryozoan colonies is unknown.

Sub-Recent buildups of *C. aciculata* are extensive along the north-eastern side of the Coorong Lagoon, between Magrath Flat and 2.5 km south of Salt Creek. The colonies are multiserial and multilayered. The architecture of these buildups differs, with those in the northern lagoon being densely packed, flat to globose coalescing mounds whereas those in the more saline southern lagoon are loosely packed, highly contorted and convoluted "pavements". Serpulid association with these Sub-Recent bryozoans is minor.

KEY WORDS: Bryozoa, Coorong, hypersaline lakes, buildups, serpulids.

Introduction

The southern Australian continental shelf and its coastal inlets (Fig. 1a) have provided an ideal environment for prolific bryozoan growth and preservation throughout the Cainozoic Era. Accumulations of their calcareous skeletons attain great thicknesses over tens of thousands of square kilometres of both open water and protected embayments. Their deposits extend from high-tide levels about protected and open coasts to beyond the edge of the continental slope (James & Bone 1992; Bone & James 1993).

The extension of bryozoan growth into sub-coastal lagoons is less well known. Today, an encrusting cheilostome anascan, *Conopeum aciculata* (MacGillivray, 1891), is found in South Australia's Coorong Lagoon (Fig. 1b), where it tolerates salinities that range from well below sea-water through to hypersaline. This bryozoan was formerly reported as *Membranipora aciculata* (Bone & Wass 1990; Bone 1991), but has now been confirmed as *C. aciculata*. A millenium ago it thrived in the Coorong waters when they were only marginally more saline than the sea.

Another occurrence of what is believed to be the same species (Bock pers. comm.) has recently been discovered in hyposaline portions of Lake Clifton, about 100 km south of Perth, Western Australia (Fig. 1c). The sub-Recent history of the Lake Clifton example is not known.

Interestingly, both occurrences are found in sub-coastal interdunal lagoons facing open oceans in mid-30 degree south latitudes. Both lagoonal systems are subject to a degree of ground water drainage via highly porous and permeable, semi-consolidated, aeolianitic, Pleistocene back-shore beach dunes. Both lagoons are similar in that significant salinity differences are manifested along their length, and these fluctuate according to seasonal water influxes. Holocene dolomite is found in both systems (Rosen & Coshell 1992). Lake Clifton was probably once a continuation of the present day Harvey Estuary (Moore *et al.* 1984) into which River Murray waters from the adjacent Darling Ranges flow at its northern, Peel Inlet end, but it is now cut off from the sea.

The Coorong still receives influxes of water directly from both the sea and its own Murray River. Although the Coorong and Lake Clifton environments possess these basic similarities, they also have significant differences in detail and salinity fluctuations which affect bryozoan establishments and growth.

In this paper, the Bryozoa and their environments are compared and summarised, with the emphasis placed on the Coorong example.

Geological Settings

The Coorong linear lagoons and Lake Clifton are products of repeated oscillation of Quaternary sea level and regional tectonic uplift. This has resulted in a sequence of abandoned sea beaches across a width suitable to create significant separation of respective sea coasts and their fossilised backshore dune deposits, both on and off-shore. This is more apparent in the South Australian example.

The present Coorong Lagoon lies in the latest interdunal corridors of successive strandings of parallel ocean-beach and backshore dunes of the Bridgewater

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Formation. This is a highly calcareous cross-bedded medium to coarse grained aeolianite. (Sprigg 1952). Similarly, Lake Clifton lies between linear shore-parallel Pleistocene ridges of calcareous sandy Tamala Limestone. These ridges show large scale cross bedding, and are composed of fine to coarse grained skeletal-fragment calcarenite with variable amounts of quartz sand (Playford & Leech 1977).

In both the Coorong and Lake Clifton regions fossil soils with rhyzoliths have developed at various levels

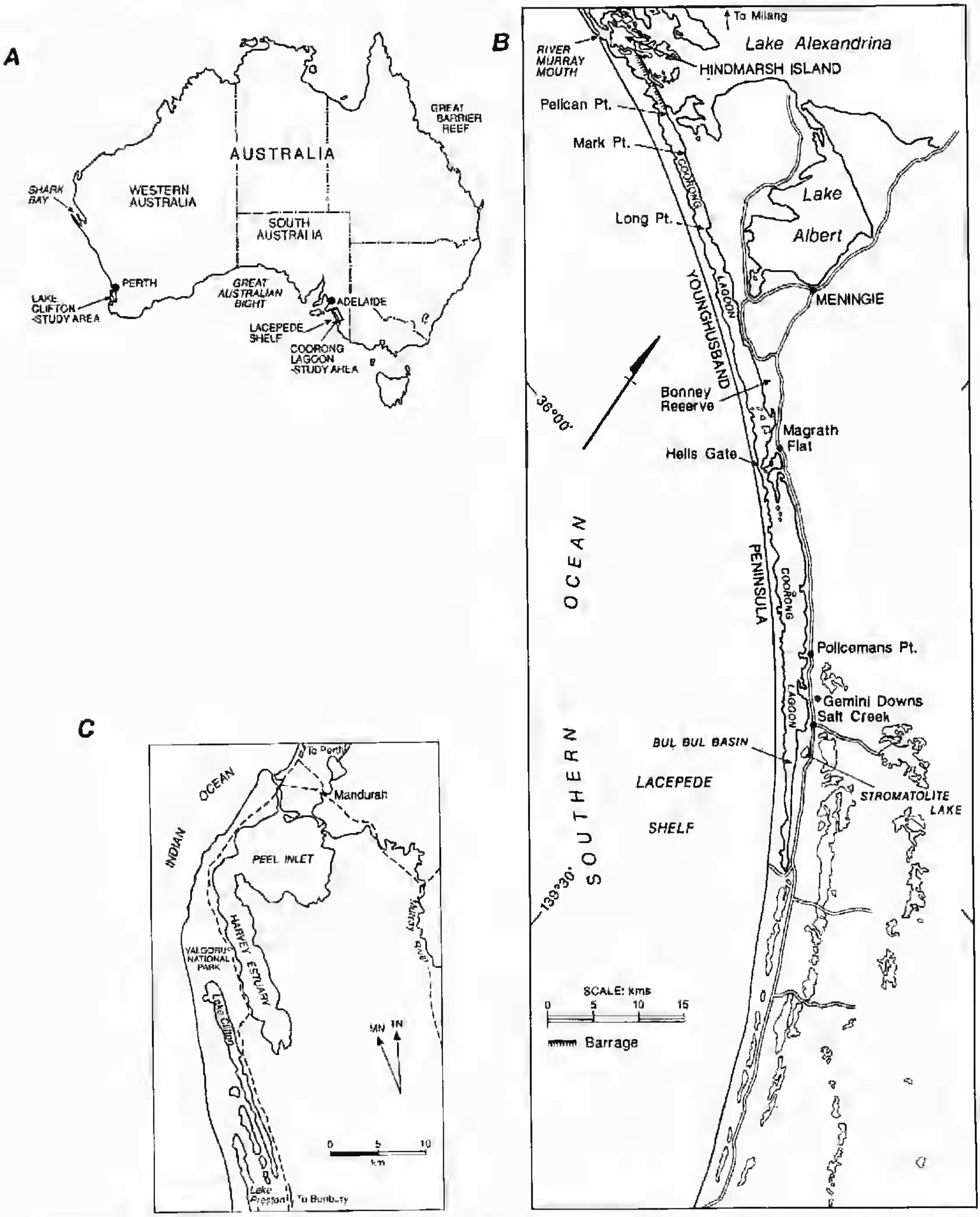

Fig. 1. la: Map of Australia showing the locations of the Coorong Lagoon and the Lake Clifton area. lb: Coorong Lagoon Location Map. lc: Lake Clifton Location Map.

within the dunes. These dunes in places include calcretised layers, if the soil forming periods were of sufficient duration. The Lake Clifton Tamala Limestone has calcrete-lined solution pipes (Semeniuk & Searle 1985) that are similar to those in the Coorong (Bone & Wass 1990). These solution pipes are features of calcrete profiles, and are formed tube-like, by calcium carbonate precipitation around regions of net vertical water percolation (Scholle *et al.* 1983) through limey dunes. In the Coorong area, erosion has removed much of the original dunes so that many of these large solution pipes are free standing by the water's edge, where they appear like the remains of petrified forests.

The Coorong and Lake Clifton interdunal areas were both inundated by the sea during the Holocene, and in each case, the consolidated aeolianites or their calcrete cappings provide excellent bases for biohermal buildups (Fig. 2).

The Lake Clifton example

The rise in sea level during the Holocene caused some of these shore-parallel limestone ridges in the southwest of Western Australia to become inundated and form a lakeland system of linear barrier estuaries and lagoons, including Lake Clifton (Fig. 1c; Searle & Semeniuk 1985). The ridges, which enclose the lagoon and separate it from the Indian Ocean 1.5 km away, dip below sea level just north of the lake and run across the narrow bryozoan-rich sediments of the Rottnest Shelf (Collins 1988) to re-emerge at Rottnest Island (Playford & Leech 1977).

The 21.5 km long, 1.0 km wide lake is replenished by winter rains falling directly on to it and by underground water from an extensive aquifer along its eastern shore. The lake is shallow, much of it being less than 1.0 m and a maximum of 3.0 m deep (Fig. 3). Water levels seasonally fluctuate up to a metre, periodically exposing and desiccating the large areas of thrombolites growing there.

A bryozoan, tentatively identified as *C. aciculata*, intimately grows over and through the clotted calcareous thrombolites (Fig. 4). The largest colony found was 2 cm in diameter. The thrombolites (Burne & Moore 1987) outwardly appear similar to stromatolites and are constructed in part by the trapping and binding of detrital sediment by cyanobacteria. As well as supporting Bryozoa, the lithoherms provide shelter for communities of fish, amphipods, isopods, decapods, nereid worms and various insects. The spaces between the clots often become filled with sediment rich in small gastropod (e.g. *Coxiella* sp.) and ostracod shells.

The salinity of Lake Clifton remains less than that of sea water throughout the year, though other lakes in the same system range from hyposaline to hypersaline. Their salinity and water chemistry, and that of the regional ground water, were investigated by Moore (1987) to elucidate why thrombolites were restricted to Lake Clifton. She found the waters of

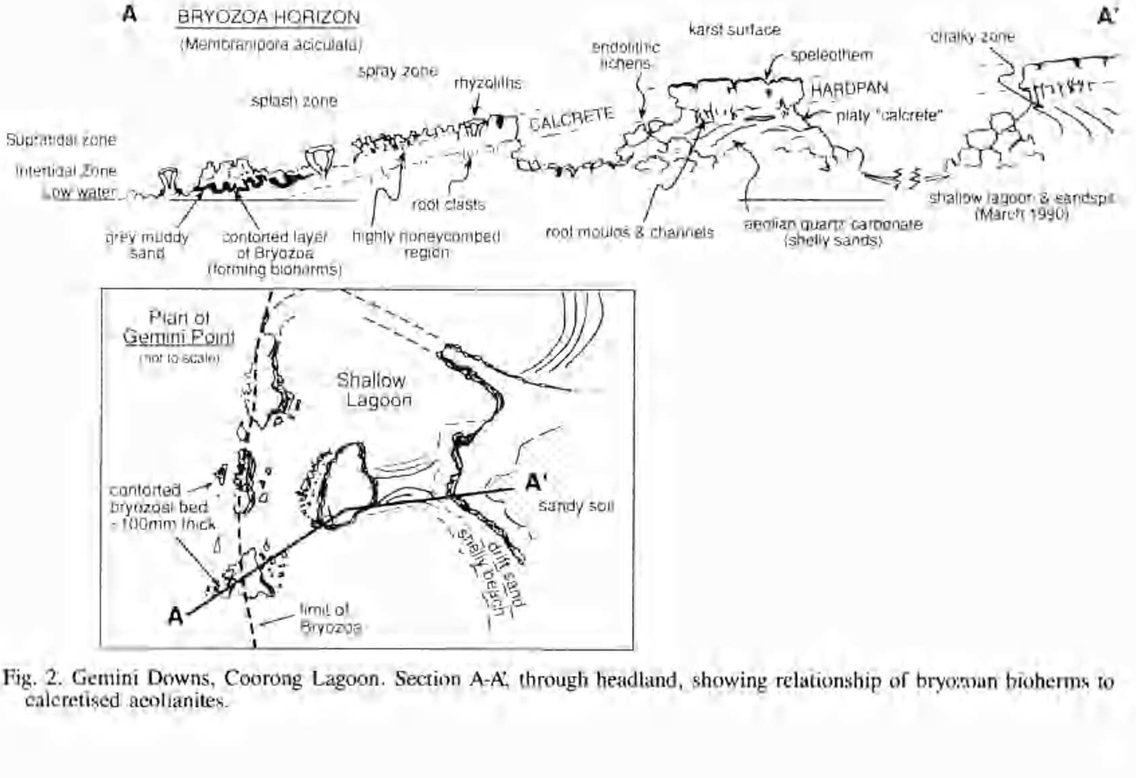

Fig. 2. Gemini Downs, Coorong Lagoon. Section A-A', through headland, showing relationship of bryozoan bioherms to calcretised aeolianites.

Fig. 3. Lake Clifton shallow water, hyposaline environment - reeds at margins in contrast to Chenopodiaciae rimming the Coorong Lagoon. Figure (holding a thrombolite) for scale.

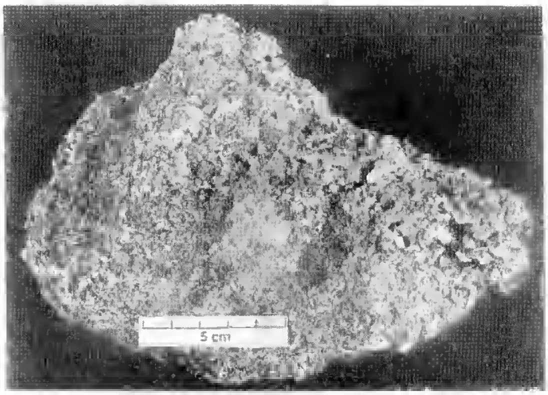

Fig. 4. Clotted, calcareous thrombolite from Lake Clifton. The bryozoan *Conopeum aciculata* is most densely intertwined in the central portion of the thrombolite.

all the lakes had ionic compositions proportionally similar to sea water, but that Lake Clifton, which receives virtually no surface run-off, obtains a large volume of its annual water from low salinity (1-2%) ground water. This water is enriched in calcium and bicarbonate (Moore 1984) which locally modifies the chemical composition of the sediment-water interface. Moore (1987) found the calcified thrombolites were consistently associated with the aquifer's discharge area along the lake's eastern shore. It follows that this, then, must also apply to the Bryozoa. Her study suggested the debouching ground waters provide a chemical environment conducive to the formation of the thrombolites that the Bryozoa encrust.

The Coorong example

Geological Setting

The Coorong (Fig. 1b) is a modern artefact of an ongoing process of successive strandings of ocean-beach backshore dunes straddled across the northern limb of the regionally uplifting Mt Gambier Arch. This uplift resulted in Tertiary seas withdrawing from the Murray Basin. Relatively rapid sealevel oscillation in response to dramatic climatic change left sub-parallel coastlines which can be tied to Milankovitch insolation signatures (Sprigg 1979; Idnurm & Cook 1980). These roughly coincide with the perturbation cycles in the earth's orbit during the late-Quaternary.

A sequence of "palaeo Coorongs" exists between ocean-beach backshore dunes to the east of the present Coorong system. These dunes have been preserved by uplift and low surface drainage over the Tertiary karst topography.

Sediment cores taken from the Coorong suggest that initially the Coorong was a protected-marine environment, becoming progressively more restricted and subject to harsh salinity fluctuations (Gostin *et al.* 1988). Stable ^{18}O isotope studies of the sub-Recent buildups of *C. aciculata* in the Magrath Flat area indicate that the Coorong was only marginally more saline than sea water when the Bryozoa grew there around a millennium ago (Bone & Wass 1990).

Later low stands of sealevel have resulted in the

Fig. 5. Sub-Recent laterally extensive buildup of *Conopeum aciculata* in the Coorong Lagoon. Width of photo is 3 m.

Fig. 6. Colonies of *Conopeum aciculata* encrusting bottle found at Magrath Flat in early 1990.

exposure of earlier formed carbonate flats (von der Borch 1976). These form terraces around both major lagoons and also around the extensively eroded and modified beach that forms an intervening string of shoals and islands in the southern Lagoon. These latter lie between the Younghusband Peninsula barrier beach-dune system and the earlier consolidated backshore calcareous dunes.

Hydrology

The elongate nature of the Coorong estuary in an area of low, winter rainfall and high, summer evaporation, and the restriction of waterflow between its two major lagoons, results in a longitudinal salinity gradient, increasing southwards (Noye 1974). This is compounded by slow mixing of less dense river water from the Murray, flowing over denser Coorong waters when levels between the sea and lagoon are appropriate (Geddes 1987). Tide, wind direction, currents, irregular bottom topography and barrage openings all contribute to the south-eastern portion remaining hypersaline year round (Noye 1974).

Unlike Lake Clifton, however, groundwater seepage via aquifers to the Coorong, although probably significant, is minor compared to the high evaporation rate (Jensen *et al.* 1984; Noye 1974). Although drainage earlier this century around Salt Creek introduced some freshwater into the Coorong for a short period, water quality in the early 1980s was probably similar to pre-drainage (Jensen *et al.* 1984), from the time of early exploration of the area through until 1864. If so, it seems that for at least a century salinities affecting bryozoan growth have been similar to those of today, and that even weir and barrage construction (1920s and 1930s respectively) may not have radically altered conditions. Prior to this, in periods of drought when the Murray dried up, the Coorong would have become saline, and major floodwaters reaching the mouth would have freshened the lagoons, just as happens today.

Salinity peaks have been noted to gradually increase over a period of years (Jensen *et al.* 1984). Such increases are terminated by the release of large quantities of Murray waters during the spring of years of heavy flooding upstream. Some of these waters reach and freshen the southern reaches of the Coorong before the cycle begins again (Jensen *et al.* 1984).

Bryozoa

In 1987 Bone discovered laterally extensive sub-Recent multi-laminar buildups (Fig. 5) of encrusting anascan cheilostome Bryozoa. Individual buildups are up to 40 cm in diameter and 30 cm high. The most extensive bioherm growth visible centres on Magrath Flat (Fig. 1c). The bryozoan was identified as *Membranipora aciculata* (MacGillivray 1891), but it is now suggested that it belongs to the genus *Conopeum*.

From mid-1987 to mid-1989 rare small scattered colonies (1 cm diameter) were found living intergrown with the serpulid, *Ficopomatus enigmaticus* (Fauvel), along the eastern margin of the Coorong from the Murray River to 2 km north of Policemans Point. The range of the living serpulids, however, was found to extend to Salt Creek (Bone & Wass 1990). In Spring 1989, conditions were apparently more advantageous for the bryozoan. It was found at Magrath Flat thriving on almost every hard surface, from the consolidated aeolianite of relict sand dunes, to bottles (Fig. 6) and tyres. Colonies up to 6 cm in diameter were found, but only as unilaminar forms (Bone 1991). Later the same year, serpulids out-competed the Bryozoa to completely cover and conceal all trace of sub-Recent bryozoan buildups in this locality. The same occurred in 1991 with serpulid banks building on those of the previous year (Fig. 7). Thus, locating the sub-fossil bryozoan buildups in this area can be difficult even when their position is known because of the thick covering of serpulids. Searches during 1990-91 for new locations of the sub-Recent bioherms in the northern Lagoon proved fruitless because of the extent and thickness of these serpulid "banks". In 1991 in particular, for more than 20 km each side of Long Point, serpulids were prevalent in the shallows (Fig. 8). They were found in cauliflower-shaped groups of worm tubes attached to almost any point of hard substrate piercing the carbonate-rich muddy sands. They were even found colonising the handle attachment hole of an old pick, growing out from it in opposite directions (Fig. 9).

Modern serpulid mounds range to >1.0 m in diameter, with multi-seasonal growth making some up to 0.5 m high. They form bioherms (Figs 7 & 8) with many other animals additional to the Bryozoa, such as crabs, isopods, copepods, amphipods, decapods, neriid worms (e.g. *Ceratonereis aequisetis* Augener, 1913) and occasionally relatively large fish.

Fig. 7. Living serpulid mounds encrusting Sub-Recent bryozoan buildups in the northern Coorong Lagoon, 1991. Figure for scale.

Methods

Mapping of the areal extent of sub-Recent buildups of the bryozoan, *C. aciculata* in the Coorong was undertaken in concert with observation of its present day range. The eastern side of the Coorong Lagoon was mapped in detail, from Pelican Point to 8 km south of Salt Creek (Fig. 1b). A boat was used on several occasions to continue mapping around reefs and islands in the central part of the lagoon, and along the western shore.

Salinity measurements and observations of colony growth were made on a monthly schedule over two years, from points along the eastern coastline. Water samples were collected for analyses at the same time. These were analysed for their concentrations of sodium, potassium, magnesium and calcium by the atomic absorption method. The salinity of the same samples were tested by a Kent electrolytic conductivity meter, temperature corrected to 25°C, and converted to ‰ (total dissolved salts). Samples of very high salinity were diluted and the salinities re-scaled, as the meter used was poorly scaled at very high values.

Results

The water salinity analyses confirm the trends of earlier studies (Noye 1974; Geddes 1984, 1987; Botting 1990). Data is biased, as sample sites had to be along the eastern shoreline. Analyses of Na, K, Mg, and Ca showed the elements were roughly in proportion to seawater, but that usually Ca < K. A water sample from the River Murray (S.A.) had Ca > K.

Flooding of the Coorong by water released through the barrages stirred up the fine carbonate mud on the floor of the Lagoon, reducing visibilty to almost zero. This, plus the greater water depth, hampered the mapping aspect of the study. Location of the Bryozoa was often by touch and not by sight, so only a small number were found. However, these were sufficient to indicate that the buildups are widespread in the southern Lagoon.

Sub-fossil buildups were found at three separate levels. The highest and most altered level lies just below the high water mark, rimming the terraces previously mentioned. The middle level is generally found 20-30 cm lower. These become exposed in summer, lying about 15 cm above the lowest water level noted. The lowest level is found approximately 50 cm lower down.

In the northern Lagoon the sub-Recent *C. aciculata* buildups form densely packed semi-flat layers (Fig. 10). The buildups in the southern Lagoon have layers which are convolute, which result in spaces occurring between the more laminar layers (Fig. 11). These spaces often contain *Coxiella confusa* and other small gastropods, minute bivalves and many different ostracods, as well as foraminifera. The latter include *Ammonia beccarii*, *Elphidium articulatum* and *Discorbis dimidiatus*, which are marine fauna, and so may be indicative of much less saline water being present in this part of the Coorong at the time of bryozoan growth. Alternatively, they may have been re-worked from sub-Recent sand dunes (Cann pers. comm.). Oogonia, the fruiting bodies of non-marine charophytes (e.g. *Ruppia sp.*, which is tolerant to a wide range of salinities from fresh to hypersaline in the Coorong today - Womersley 1984) are also found within these spaces.

In both 1989 and 1990 the bryozoan Cyphonaute larvae had settled and begun to bud asexually by the beginning of October. In 1990 at the end of the first week in October colonies 1.0 cm in diameter were common and widespread, growing in the central southern Coorong, both along the shore and around islands, and on "reefs". The most southerly discovery of living *C. aciculata* was on the edge of the shallow hypersaline Bul Bul Basin, 4.5 km south of Salt Creek. These rare colonies were small encrustations on the sides of consolidated terraces belonging to earlier carbonate flats of a higher water level (Table 1).

Colony establishment time is not known for either year at the northern end of the study area at Pelican Point. At the northern end of the Coorong, small colonies (Table 1) were common both years in the fresh waters adjacent to the barrages, where lake waters are known to seep through.

A sketch and cross-section over the Point adjacent to the Gemini Downs Boat Ramp illustrate a typical southern Lagoon environment showing relationships between features and the sub-fossil accumulations (Fig. 2). These deposits are extensively intergrown around solution pipes, and some contorted bands (5-10 cm thick) contain teepee-like structures and possible fractures. They are underlain by grey, semi-plastic mud.

TABLE 1. *Size of colonies of modern* Conopeum aciculata *on north-eastern margin of Coorong Lagoon. Size differences were transitional between adjacent locations. "Warnecke Point" is an unnamed feature lying south of Hells Gate, on the Warnecke property.*

Location	Bryozoan Colonies – Maximum Size (cm) 1989	1990
Pelican Point	2.0	1.0
Mark Point	2.0	1.5
Long Point	–	1.5
Bonney Reserve	–	3.0
Magrath Flat	6.0	4.0
"Warnecke Point"	7.75	–
Policemans Point Boat Ramp	3.0	3.0
Gemini Downs Boat Ramp	2.0 (rare)	2.75 (rare)
4.5 km south of Salt Creek	1.0 (rare)	1.5 (rare)

Fig. 8. Close-up of living serpulid mounds, showing their similarity to stromatolite growth form. The destruction of the upper, central portion is caused by fishermen dragging their boats across the bioherms. Individual mounds average 1 m in width.

Discussion

Due to conditions prevailing in the northern Lagoon favouring prolific growth of thick serpulid colonies in 1989 and 1990, searches of this area did not reveal new locations of sub-fossil Bryozoa. In the southern Lagoon, however, conditions were less beneficial to both serpulids and Bryozoa. In 1990 serpulid growth was less abundant than in the northern Lagoon, but 1991 brought even poorer growth. Consequently ubiquitous sub-fossil sub-Recent bryozoan buildups were often exposed in the southern Lagoon.

The convoluted nature of many of the layers of the sub-fossil bryozoan buildups found in the southern Lagoon were unusual in that instead of being parallel to each other like those found in the north, they were often highly contorted. Some twist upwards, only to turn sharply and grow back on themselves, thus leaving "holes". Others were regularly laminated similar to those found in the northern Lagoon where one layer is laid down directly on the last. The growth of bryozoan colonies is largely affected by changes in their environment and this can cause changes in colony morphology (McKinney & Jackson 1989). Thus it may be possible to trace particular periods of environmental change over large areas of the lagoons through examination of the growth patterns of different buildups, if the contorted layers do indeed have a similar pattern at a particular time.

The three separate levels of buildups found in the southern Lagoon may have grown concurrently, but it is more likely that as water levels are known to have changed in the lagoons that each might belong to a different time period. High water levels prevented clear mapping of these different levels. Radiocarbon dating analyses currently being undertaken may elucidate these and other timing uncertainties.

Microfossils found within the convoluted layers of bryozoan buildups include Oogonia from algae characteristic of marginal marine and non-marine saline lakes. The Foraminifera are all extant, benthic species. Cann (pers. comm.) suggested (i) that they could have become encased by bryozoan growth after being washed in after eroding out of the surrounding aeolianite, or (ii) that having crawled there, the Foraminifera were trapped and died, as the fast growing *C. aciculata* entombed them.

New colonies found a week into October 1990 were common and widespread in the southern Lagoon. They were all about 1.0 cm in diameter. Colonies 0.2 cm larger or smaller than this were not present. Thus, a switching signal for the beginning of asexual budding must have occurred almost concurrently over a large area. Actual growth rate was not determined, as a precise settlement timing is not known, but growth certainly appears to have been rapid compared to that

Fig. 9. Serpulid colony growing through the handle-hole of a pick-axe, found in the northern Coorong Lagoon in 1991.

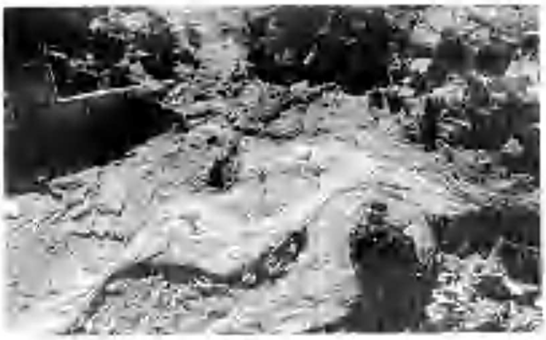

Fig. 10. Common growth form of sub-Recent *Conopeum aciculata* in the northern Coorong Lagoon. The multilayered habit has flat layers densely packed and relief is low.

of most Bryozoa (McKinney & Jackson 1989). Growth ceases and the colony dies once it is exposed.

The rate of multilaminar layer formation is also unknown. Only one example of multilaminar growth was found in present day colonies. The colony is located on the internal walls of a solution pipe, where it is well protected from high energy wave and storm damage. It may be that multilayer growth occurred in the one season, or that growth of the second layer occurred in a later season coincidentally on the earlier skeletal remains.

Today, the living Bryozoa are only found growing on solid objects whereas many of the sub-fossil buildups form pavements (5-8 cm thick) that appear to have grown out laterally from the terraces, over the soft carbonate muds. Other bands, up to 20 cm thick, appear to have grown out laterally from consolidated aeolianite, so that now they are completely unsupported, other than for the hard rock they rim. It appears they may have originally grown over unconsolidated sediment, since eroded away.

Observations, coupled with analyses, show that very high salinities are lethal to *C. aciculata* . These high salinities occur early in summer in the southern Lagoon, resulting in maximum colony size being relatively small, especially compared to those in the northern Lagoon. This can be seen from Gemini Downs southwards to Salt Creek, where colony size ranges from 2.75 cm down to 1.5 cm, suggesting a very short growth period, particularly in 1990. The switch to the salinity level lethal to the organism could not be pinpointed, as samples were collected nearshore and thus did not always allow for local and daily salinity variations, due to slow mixing. However, even here daily variations are observed, confirmed by Botting & Associates (1990).

Fig. 11. Common growth form of sub-Recent *Conopeum aciculata* in the southern Coorong Lagoon. The multilayered habit is convoluted and distorted, and results in many buildups becoming fragmented.

Conclusions

1. Sub-Recent buildups of the bryozoan *Conopeum aciculata* are widespread in both the northern and southern lagoons of the Coorong. The buildups are up to 30 cm high and 40 cm in diameter. Growth form in the northern Lagoon is multiserial, multilayered, gently arcuate and compact. Growth form in the southern Lagoon is multiserial and multilayered but the layers are highly convoluted.

2. Modern colonisation of hard substrates in the Coorong by *C. aciculata* is seasonal, occurring in the spring; and even more widespread than the sub-Recent occurrences. Colony size increases rapidly, utilising multiserial, unilaminar growth form. Maximum colony size is 6 cm in diameter, occurring in the northern Lagoon. Serpulids frequently outcompete the Bryozoa, thereby concealing evidence of annual bryozoan presence.

3. Salinity in the Coorong increases southwards and increases seasonally up to 60%, due to high evaporation in summer. The higher salinities are lethal to the Bryozoa but not to the serpulids. Similarly, exposure due to summer water-level fall kills the Bryozoan but not the serpulid colonies. Cyphonaute larvae are able to survive the high salinities, and re-colonise when conditions are optimal. Small bryozoan colonies occur in Coorong hyposaline waters adjacent to the fresh-water lakes at the northern reaches of the Coorong.

4. Modern *C. aciculata* occurs intimately associated with thrombolites in fresh water on the eastern margin of Lake Clifton, Western Australia.

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References

BONE, Y. (1991) Population explosion of the bryozoan *Membranipora aciculata* in the Coorong Lagoon in late 1989. *Aust. J. Earth Science* **38**, 121-123.

_____ & WASS, R. (1990) Sub-Recent bryozoan-serpulid buildups in the Coorong Lagoon, South Australia. *Ibid.* **37**, 207-216.

_____ & JAMES, N. P. (1993) Bryozoans as carbonate sediment producers on the cool-water Lacepede Shelf, southern Australia. *Sed. Geol.* (in press).

BOTTING, J. & ASSOCIATES (1990) Coorong and Murray mouth working group project: Preliminary assessment of departmental data base. (Engineering & Water Supply, Adelaide).

BURNE, R. V. & MOORE, L. S. (1987) Microbialites: Organosedimentary deposits of benthic microbial communities. *Palaios* **2**, 241-254

COLLINS, L. B. (1988) Sediments and history of the Rottnest Shelf, southwest Australia: A swell-dominated, non-tropical carbonate margin. *Sed. Geol.* **60**, 15-49.

ESTEBAN, M. & KLAPPA, C. F. (1983) Subaerial exposure pp.1-54. *In* P. A. Scholle, D. G. Bebout & C. H. Moore (Eds), "Carbonate Depositional Environments". *AAPG Memoir* **33**.

GEDDES, M. C. (1987) Changes in salinity and the distribution of macrophytes, macrobenthos and fish in the Coorong Lagoons, South Australia, following a period of River Murray flow. *Trans. R. Soc. S. Aust.* **111**, 173-181.

_____ & BUTLER, A. J. (1984) Physicochemical and biological studies on the Coorong Lagoons, South Australia, and the effect of salinity on the distribution of the macrobenthos. *Ibid.* **108**, 51-62.

GOSTIN, V. A., BELPERIO, A. P. & CANN, J. H. (1988) The Holocene non-tropical coastal and shelf carbonate province of southern Australia. *Sed. Geol.* **60**, 51-70.

IDNURM, M. & COOK, P. J. (1980) Paleomagnetism of beach ridges in South Australia and the Milankovitch theory of ice ages. *Nature* **286**, 699-702.

JAMES, N. P. & BONE, Y. (1989) Petrogenesis of Cenozoic temperate water calcarenites, South Australia: A model for meteoric/shallow burial diagenesis of shallow water calcite sediments. *J. Sed. Pet.* **59**, 191-203.

JENSEN, A., HOEY, P., KOPLI, P., SHEPHERD, R., TILL, M. & WEINERT, M. (1984) The effects of drainage on groundwater behaviour in countries Cardwell and Buckingham and the effect on the Coorong: A report for the Minister of Water Resources 1981-1983. *S.A. Dept Environment and Planning* **66**, 8-65

MACGILLIVRAY, P. H. (1891) Description of new or little known Polyzoa. *Trans. R. Soc. S. Aust.* **3**, 77-83.

MOORE, L. S. (1987) Water chemistry of the coastal saline lakes of the Clifton-Preston lakeland system, south-western Australia, and its influence on stromatolite formation. *Aust. J. Marine & Freshwater Res.* **38**, 647-660.

_____ KNOTT, B. & STANLEY, N. (1984) The stromatolites of Lake Clifton: Living structures represent the origins of life. *Search* **14**, 309-314

_____ & TURNER, J. V. (1989) Stable isotopic, hydrogeochemical and nutrient aspects of lake-groundwater relations at Lake Clifton. pp.201-213. *In* G. Lowe (Ed.) "Proceedings of Swan coastal plains groundwater management conference" (W. Aust. Water Resources Council, Perth).

NOYE B. J. (1974) The Coorong - An introduction. pp.1-79 *In* J. Noye (Ed.) "The Coorong". *Dept. Adult Education, Univ. Adelaide Pub.*, **39**.

PLAYFORD P. E. & LEECH, R. E. J. (1977) Geology and hydrogeology of Rottnest Island. *Geol. Surv. West. Aust. Rep.* **6**.

ROSEN, M. R. & COSHELL, L. (1992) A new location of Holocene dolomite formation, Lake Hayward, Western Australia. *Sedimentology* **39**, 161-166.

SEARLE, D. J. & SEMENIUK, V. (1985) The natural sectors of the Inner Rottnest Shelf coast adjoining the Swan coastal plain *Jour. R. Soc. W. Aust.* **67**, 109-115

SEMENIUK, V. & SEARLE, D. J. (1985) The Becher Sand, a new stratigraphic unit for the Holocene of the Perth basin. *Ibid.* **67**, 109-115.

SPRIGG, R. C. (1952) The geology of the South-east Province, South Australia, with special reference to Quaternary coastline migrations and modern beach developments. *Dept. of Mines, South Aust. Bull.* **29**.

_____ (1979) Stranded and submerged sea-beach systems of southeast South Australia and the aeolian desert cycle. *Sed. Geol.* **22**, 53-96.

VON DER BORCH, C. C. (1964) The distribution and preliminary geochemistry of modern carbonate sediments of the Coorong area, South Australia. *Geochim. Cosmochim. Acta* **29**, 781-799.

_____ (1976) Stratigraphy and formation of Holocene dolomitic carbonate deposits of the Coorong area, South Australia. *J. Sed. Pet.* **46**, 952-966.

WOMERSLEY, H. B. S. (1974) Plant life in the Coorong. *In* J. Noye (Ed.) "The Coorong." *Dept Adult Education, Univ. Adelaide Pub.* **39**, 81-88.